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MAINTENANCE OF FERTILITY OF SHALE SOILS IN A TRADITIONAL AGRICULTURAL SYSTEM IN CENTRAL INTERIOR PORTUGAL

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ABSTRACT.—The traditional techniques practiced by subsistence farmers dwelling in the shale foothills of the Serra da Estrela mountains in central interior Portugal have created and maintained fertile soil on this intrinsically marginal land for the past 400 years or more. To describe and explain these techniques, data were recorded for an area at 600 m above sea level at the headwaters of the Pracais river in the county of Pampilhosa da Serra, district of Coimbra. The 23 remaining residents of a group of three villages here provided ethnographic insights. In the summer temperatures may reach 40° C and it rarely rains, but in the winter temperatures often fall near zero (though rarely below) and about 2 m of rain fall. The rain has cut deep, steep-sided valleys into the shale from which soil is readily washed. The clay soil that forms from this ancient shale is not fertile. Church records show that people have inhabited the Pracais valley for at least four centuries, but probably longer. During this time, they have built hundreds of kilometers of stone retaining walls to facilitate cultivation and irrigation, and to control erosion. To create and maintain fertility they cut brush from the heathlands that cover the ridgetops above the valleys, mix it with goat excrement, and bury it in the soil of the cultivated terraces. The rate at which organic matter is added to soil was measured to be about 12 metric tons dry weight per hectare per year. Chemical analyses of vegetation from heathland species, and of their mixture with goat excrement, determined that this rate was slightly more than adequate to replace the nitrogen, phosphorus and potassium removed from the soil with the annual corn harvest. Annual primary productivity in the heathlands was measured to be about 210 g dry matter per square meter. Vegetation harvested from about 6 to 8 hectares of heathland is required to maintain the fertility of one hectare of cultivated terrace. Thus, the nearby heathlands are as much a part of the economic resources of the village as are the sheds, houses, and cultivated terraces.

RESUMO.—Este estudo descreve processos de manutenção da fertilidade do solo através de técnicas tradicionais, empregues por agricultores em regime de subsistência, que vivem nas encostas da Serra da Estrela, no interior Centro de Portugal. Os dados foram recolhidos essencialmente no grupo de aldeias, junto do rio Praçais, na freguesia de Cabril, concelho de Pampilhosa da Serra, distrito de Coimbra. A pluviosidade anual no local atinge de metro e meio a dois metros e um quarto, principalmente entre os meses de Outubro e Março. Os vales escarpados são susceptíveis de uma intensa erosão, em direcção ao leito do rio, sob acção das chuvas. Raramente chove nos meses de Julho e Agosto, e as temperaturas atingem os 30 centígrados. Os registos paroquiais indicam que a população habita esta zona há pelo menos 4 sèculos, mas muito provavelmente, há mais tempo. Ao longo dos anos, as populações foram erigindo centenas de quilômetros de muros de pedra para suporte da terra, ao longo do vale do Praçais. Destinam-se a segurar o solo para possibilitar o seu cultivo e irrigação e para evitar a erosão. O solo argiloso que é arrastado pelo leito do rio é constituido principlamente por minerais de ilite, e é praticamente infértil. A fertilidade é produzida e mantida, em primeiro lugar, pela adição de matéria orgánica, constituida por mato cortado nas charnecas que ocupam os cumes dos vales, misturado com excrementos de cabra, e enterrada no solo dos terracos de cultivo. Através de observação directa e inquérito aos agricultores, medindo as reas e pesando e medindo os montes da mistura, foi possível calcular que a taxa de adição de matéria orgánica no solo era cerca de 12 toneladas de matéria seca, por hectare, por ano. Análises químicas de amostras da vegetação empregue, obtidas na zona, bem como da sua mistura com os excrementos de cabra, permitiram verificar que esta taxa de adição é ligeiramente superio à necessaria para a substituição do azoto, fôsforo e potássio removidos do solo pelo cultivo anual de milho. A productividade primária nas charnecas, onde o mato cresce, foi determinada com sendo, aproximadamente, de 230g de matéria seca por metro quadrado, por ano. Cerca de um terço destas zonas altas , terreno baldio ou pedregoso. Assim, são necessarios cerca de 8 hectares de terreno com mato para manter a fertilidade de um hectare de terreno cultivável, nos terraços. Isto demonstra claramente a importância das charnecas e matagais circundantes nos recursos econômicos essenciais à tradicional agricultura de subsistência desta região.

RÉSUMÉ. — Les agriculteurs de subsistance des collines basses de la Serra da Estrala, au centre du Portugal, ont aménagé il y a quatre cents ou plus et réussi, depuis, à conserver des sols fertiles dans une région schisteuse intrinsèquement marginale. Pour décrire et expliquer les techniques traditionnelles utilisées, nous avons rassemblé des données dans une zone à 600 m au-dessus du niveau de la mer située en amont de la rivière Pracais, dans le comté de Pampilhosa da Serra, dans le district de Coimbra. Les vingt-trois derniers habitants d'un groupe de trois villages ont fourni des informations ethnographiques précieuses. Durant l'été, la température peut atteindre 40°C et il pleut rarement, mais en hiver, le mercure descend souvent à zéro, rarement au-dessous, et il tombe environ 2000 mm de pluie. La pluie a creusé dans le schiste des vallées profondes à flancs escarpés et la terre est facilement emportée. Le sol argileux qui compose cet ancien schiste n'est pas fertile. Les registres paroissiaux montrent que la vallée de la Pracais est habitée depuis au moins quatre cents ans. Durant cette période, les habitants ont construit des centaines de kilomètres de murs de soutènement en pierre pour faciliter l'agriculture et l'irrigation, et contrôler l'érosion. Pour enrichir le sol et le conserver fertile, ils coupent les brousailles pris dans les landes qui se trouvent sur les crêtes surplombant les vallées, y ajoutent du fumier de chèvre et enterrent le tout dans le sol des terrasses cultivées. Environ 12 tonnes métriques (poids sec) de matière organique sont ajoutées par hectare par année. L'analyse chimique des espèces végétales des landes et du mélange obtenu avec le fumier de chèvre montre que cette quantité est légèrement plus qu'adéquate pour remplacer l'azote, le phosphore et le potassium retirés du sol avec la récolte annuelle de maïs. La productivité primaire des landes a été évaluée à environ 210 g de matière sèche par mètre carré. De six à huit hectares de landes fournissent assez de matière végétale pour maintenir un hectare de terrasse cultivée fertile. Ainsi, les landes voisines font autant partie des ressources économiques du village que les bâtiments, les maisons et les terrasses cultivées.

INTRODUCTION

Fossil fuels, such as coal and oil, are used extensively to manufacture inputs to modern agriculture, while pre-fossil fuel agriculture, here termed "traditional," is principally solar powered. The study of traditional agriculture, where it has supported a population for hundreds of years, can reveal how aspects of its culture and technology overcome ecological, environmental, and social problems to meet the material and emotional needs of its practitioners. The cultural aspects of traditional agriculture include the practices by which the technology is learned, transmitted to subsequent generations, and made resilient against short term vicissitudes of environment or against invasion by inappropriate technology. As part of culture, these practices are celebrated as life-sustaining activities that create and strengthen among individuals ties that form a self- consciously bound community. With this understanding, we can participate more effectively in directing and appreciating our own modern agricultural technology and culture.

Often, agriculture becomes established in areas that are naturally fertile; but the people described here have practiced traditional agriculture where soils are naturally sparse and infertile. Thus, collecting and holding soil, and creating and maintaining its fertility, were important and unusual aspects of their technology. This study combines the methods of cultural anthropology, history, quantitative field ecology, and chemical laboratory analyses to provide both scientific and cultural explanations for the traditional practices of these people to create and restore the fertility of their cultivated soil.

ETHNOGRAPHIC SETTING

To the west and south of the Serra da Estrela, Portugal's highest range of mountains, the large stream, Rio Pracais, descends its steep-sided, twisting, deep valley about 15 km to the town of Pampilhosa da Sera, where it joins the Unha river in the Tejo river drainage (Figure 1). At its headwaters lie three villages: Sobralinho, Malho, and Sanguasuga, called collectively Ribeiros, which means streams. Ribeiros is in the parish of Cabril, about 40° 6′ N, 7° 56′ W (Greenwich), at ca. 700 m elevation, with ridge tops 100 m to 250 m above. Downstream from Ribeiros, the valley of the main stream soon becomes so deep and steep that agricultural development has occurred mostly along tributaries. On a tributary about 6 km downstream is the village of Pracais. Two kilometers further, over the ridge, along the next major tributary lie the three villages of Piscanseco. The whole Pracais drainage lies within the county (Concelho) of Pampilhosa da Sera, in the state (Distrito) of Coimbra, Portugal.

METHODS

I first visited the Pracais valley in 1980, when I was taken to the villages of Piscanseco by an adult who was born and raised there. It was apparent that the only agriculture then practiced was based on pre-fossil fuel technology. Families owned the land they worked and worked on their own account, primarily for subsistence.

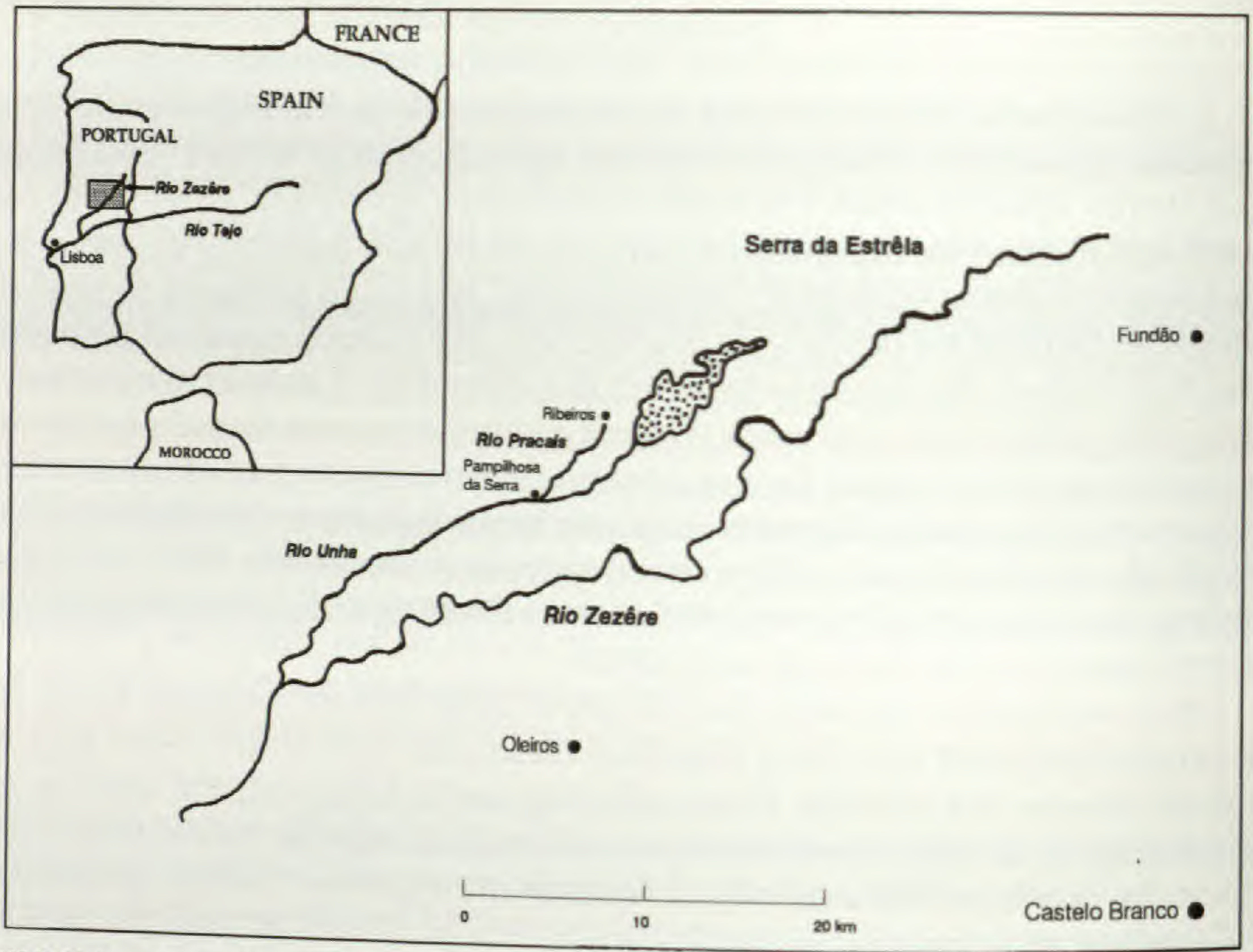

FIGURE 1.— Location of Rio Pracais and the Ribeiros village group within Portugal.

I returned to the Pracais valley briefly in 1983 and 1984, and subsequently lived in Ribeiros from August through December 1987 to study the agricultural technology practiced there. I spent six equally spaced weeks during this time in Lisboa to work with the Laboratorio Quimica Agricola Rebelo da Silva (LQARS), the Portuguese Agricultural Ministry's chemical laboratory, to analyse samples, or in Oeiras at the Herbarium of the National Agronomy Station to identify plants, or at the University of Coimbra to examine the Archives and weigh plant material. I returned to the Pracais valley briefly in July 1993.

In addition to personal observation of the weather in Ribeiros, I estimated the general climate in recent years by examining the records of the Portuguese National Meteorological Service at the Instituto Superior de Agronomia in Lisboa, where records from locations near Ribeiros were available for some years beginning in the early 1960s. Monthly rainfall data were available for the towns of Vidual, Cabril, and Fejao, all within 10 km of Ribeiros. Monthly average daily temperature maxima and minima, total monthly evaporation, and hours of sunshine were available only for the more distant and larger small cities. Fundao (34 km east) was chosen as representative because of similar altitude and terrain.

During this time, I observed and measured the terrain, which has been extensively modified by the construction of tens of kilometers of terraces. These are an integral part of the agricultural technology because most of the annual crops are cultivated in soil they retain. I observed the forests and heathlands, which play important roles in this subsistence economy. I observed the cultivated crops, including the timing and technology practiced by the people who cultivate them.

Much information was gathered by interacting directly with the permanent residents themselves. Two married couples provided me food and shelter, and introduced me to some of the other residents of Ribeiros. This endorsement by my native hosts was essential for other residents to speak freely with me. Estabrook (1994) presents a detailed description of interview and observation methods used to gather data directly from residents.

I used two approaches to estimate the number of residents in Ribeiros in 1900 and 1940. Church records in the archive of the University of Coimbra and civil records in the town of Pampilhosa da Serra indicate baptisms in towns in the Pracais valley, including Ribeiros. Numbers of hearths and numbers of people were estimated for 1900 and 1940 using national census counts from 1890 and 1930 of people per hearth and baptisms per hearth for the nearby towns of Cabril and Pampilhosa da Serra, because Ribeiros was too small to be reported. The ratios from these two towns were applied to the available baptism counts for Ribeiros. I also estimated the number of people in Ribeiros in 1940 from the number I observed in 1987 and the fraction of terraces I observed to be under cultivation in 1987.

An important aspect of the technology by which people create and maintain soil fertility is by adding large amounts of organic matter to the soil. I observed how people collect this organic matter as brush from the heathlands, enrich it with goat excrement, and allow it to begin decomposition, before they add it to the soil at specific times. Corn (*Zea mays* L.) is a major crop, which is harvested in October. I was able to observe and measure this harvest. I estimated the amount in dry metric tons per hectare of organic matter that people added to the soil to restore fertility after they harvested this corn crop. People carry baskets of organic matter to the plot where soon it will be spread out and mixed with the soil. They empty baskets into a pile against the wall at the uphill side of the plot. With the cooperation of their carriers, I weighed several baskets using a hand-held, spring-loaded scale. The number of baskets emptied to make a pile, together with the volume of the pile, was used to estimate the weight of a cubic meter of organic matter. I sealed a sample of organic matter in a plastic bag and later, in a laboratory in Coimbra, weighed, dried, and reweighed it to determine percent dry weight. Farmers made four piles during my stay. For each, I measured the volume of the pile and the area of the plot over which it would be spread.

Just before its harvest in October, I measured corn yield in the irrigated streamside plot known to be cultivated using traditional practices. The number of ears on all stalks in three areas of four m^2 each were counted. Also counted were the numbers of grains on several ears. Later in Coimbra, I weighed 100 grains. From these data, yield in kg of dry seed per hectares was calculated. The residents allow the seeds to dry thoroughly on the stalks before harvest so that they may be more easily removed from the ears and milled into flour for bread. Barber and Olson (1968) used chemical analysis to estimate the amounts of plant nutrients contained in corn plants producing 10,000 kg of dry grain grown in Wisconsin. They report 200 kg N, 42 kg P, and 205 kg K. Recognizing that corn plants in Ribeiros may differ somewhat from this composition, these removal rates per 10,000 kg dry grain, together with the yield estimated for the plot in Ribeiros, were used to estimate the rate at which nutrients are removed from the soil in that plot per corn harvest per hectare.

I homogenized many samples of *estrume* (as the residents call their mixture of heathland plants and goat excrement) and analyzed it by chromatography at

LQARS to determine g/kg of nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. In all four plots, estimates of the amounts of nitrogen, phosphorous and potassium removed from the soil with the corn harvest were compared to the amounts added to the soil in organic matter. Vegetation samples of the nine principal plant species in the heathlands were also analysed in the same way. Comparing these measurements with those for estrume provides clear evidence of the contribution of goats to estrume (as shown in Table 3, below).

The area presently and formerly used by the residents is essentially the entire upper drainage basin (Figure 2). Fifty-five soil samples were taken from 23 sites throughout this area, including uncultivated clay, heathland, irrigated streamside and terraced plots, and unirrigated terraced plots (see Table 4, below). Some of the plots were still actively cultivated, though others had been abandoned for from two to 20+ years. Soil sample sites were chosen in order to measure and compare the nature of various local soils of interest to this study. The uncultivated clay represents soil before residents invest in it. The one or two cm of soil over the rock outcrops from which the heathlands grow may have been a source of soil to pioneering cultivators. Actively cultivated plots have received hundreds of years of annual influxes of organic matter, and when irrigated have remained wet all year long. Recently abandoned plots may reflect the cultivator's intent to abandon. Long abandoned plots may show the restorative effect of fallow. Measurements of soil samples from each area of interest will be presented and discussed below.

At most sites, about 10 soil cores, each about two cm in diameter and of lengths depending on site from superficial to 40 cm, were taken from within about a two square meter area. In cultivated plots, about the top 10 cm are disturbed when organic matter is added or new crops are planted, so the 5-6 cm section was usu-

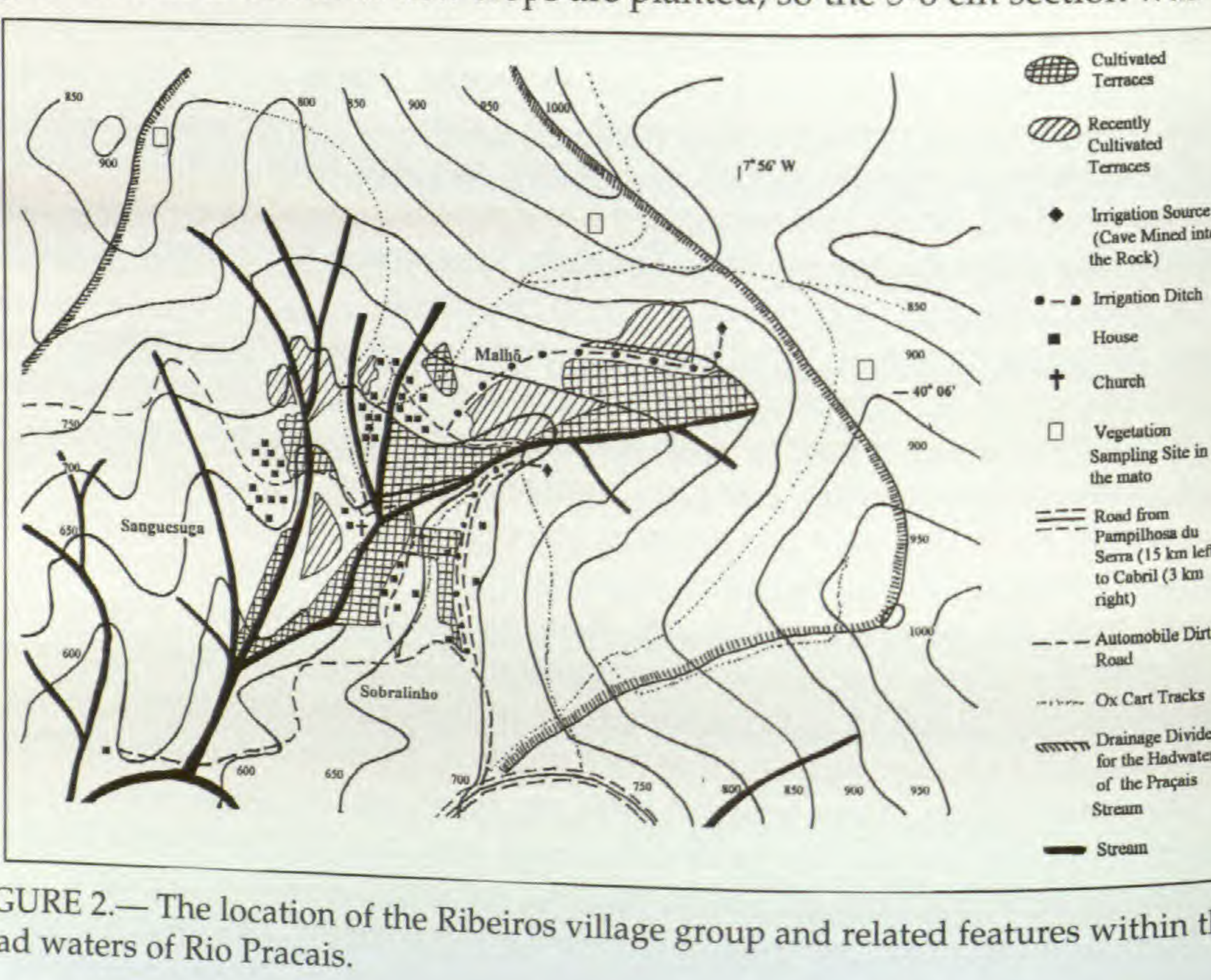

FIGURE 2.— The location of the Ribeiros village group and related features within the head waters of Rio Pracais.

ally taken from these disturbed strata, along with a section at 20-21 cm just below the actively disturbed depth. In a few cultivated plots the soil was deep enough to allow a section from 40 cm. Within a plot, sections from the same depth were then combined and homogenized to make a single soil sample. Values for N, P, and K may be affected by periodic additions by farmers of organic matter to cultivated plots, as described above. Samples from such plots were taken about two weeks before the corn was harvested in early October. Soil samples were analysed at LQARS for particle size, water holding capacity, organic matter, total nitrogen, carbon to nitrogen ratio, extractable phosphorus and potassium, pH (both in water and in dilute KCl), and cation exchange capacity

Because people collect large amounts of vegetation from the heathlands to add to the soil in their cultivated terraces to restore its fertility, the heathlands are an important resource for their agricultural technology. To estimate the ratio of area of heathland needed to support area of cultivated terrace, I measured the rate of growth of vegetation in the heathlands. I cut, removed, dried and weighed all the vegetation from sample plots in two distinct areas. In one area that people said had been cut to near ground level 4 years earlier, which is the regeneration interval allowed before they clear-cut vegetation again from the same place, I clearcut plots covering two square meters. In the other area, which had burned over in a local fire eight years earlier, I clearcut plots covering six m^2. Because the purpose of this vegetation sampling was to produce an estimate of the rate of primary productivity in the heathlands that is as accurate as possible, all the vegetation from plots of the same age was pooled to avoid pseudo-replication. Dividing previously estimated rates per unit area at which people add organic matter to soil to restore fertility after a corn harvest by rates per unit area at which vegetation grows in the heathlands estimates the ratio of area of heathland needed to support area of cultivated terrace.

RESULTS

Climate. — Monthly temperature, rainfall and evaporation data are presented in Table 1. Lows at or below freezing occur in a dozen or so days spread over the months from November through April with average lows in the single digits C and average highs in the teens. Rains typically begin in September or October, becoming strong in November, intense in December, strong again in January and February, moderate in March, taper through April and May to sparse in June, and absent in July and August. Typical annual rainfall in Vidual, Cabril and Fejao (all within 10 km of Ribeiros and about the same altitude) is from 1.5 to 2.2 m of which about 80% falls from November through February. Direct sun and drying of the air occur infrequently during these months, as shown by the sun hours and evaporation potential in nearby Fundao. By April it is drier, sunnier, warmer, and freezing is improbable. June, July, and August are very hot and dry, with highs sometimes near 40° C. The timing and amount of rains are quite variable from year to year, and to a lesser degree from place to place. Occasionally, rains will start late, or annual rainfall will barely exceed 1000 mm. Some aspects of the agricultural practices anticipate this uncertainty.

Terrain and terraces. — The Pracais flows sw away from Portalinha Pass (900 m), which is 1.5 km ne from the church (600 m) shown by the cross in Figure 2. The principal cirque has a radius of about 1 km for its northeastern half, but the divides narrow to about 1 km apart 2 km downstream from the church. Many streams flow out of this cirque, joining in and below Ribeiros as the divides begin to narrow. A lesser ridge, from northwest of the pass, slopes SW to the middle cluster of residences and divides the cirque into two lesser cirques: one faces west below Portalinha pass and carries the main stream; the other faces south below a high ridge and carries one of its many tributaries. The beds of these two streams are 1 to 2 m deep and so difficult to cross that they divide the lower basin into the three small villages mentioned above: Malho on the small ridge between them; Sobralinho on the NW facing slopes south of the main stream; and Sanguasuga, now completely uninhabited, on a South-facing promontory West of this tributary, which joins the main stream 300m below.

These slopes have been developed into productive, cultivated plots in a variety of ways. In the past, rye (*Secale cereale* L.) was cultivated during the winter in distant, unterraced, heathland plots without irrigation. Perhaps because of their distance from the residence cluster, these plots have been abandoned. Formerly most and presently all cultivated soil is held behind stone walls. These are built high enough to hold soil at a depth sufficient to grow crops and to create a level terrace wide enough to stand on to cultivate. Walls also protect soil from erosion and facilitate irrigation.

Approximately 40 km of retaining walls are in the area represented by the map in Figure 2. They have been built in three basic styles. North of the main stream, beginning several hundred meters east of Malho, continuing downstream through the villages and below, are wider, sloping, cultivated plots behind streamside walls, each an ownership parcel 10 to 30+ m long. Below Malho on the northwest facing slopes of Sobralinho, there are similar plots south of this stream as well. A second style occurs on the south facing slopes north of, and farther from, this main stream. These consist of series of nearly level cultivated terraces, behind retaining walls from 1.5 to 2.2 m tall. The gullies of streamlets that run southward or westward have frequently been breached by masonry walls and backfilled to produce yet a third kind of cultivated terrace.

TABLE 1. — Data to estimate weather in Ribeiros

		‡	J	F	M	A	M	J	J	A	S	O	N	D
Cabril	*1965*	*r*	241	128	194	12	18	3	0	0	131	261	274	175
Vidual	*1978*	*r*	214	328	89	195	109	77	0	1	38	76	68	568
Fejao	*1978*	*r*	256	324	123	171	94	83	0	0	36	76	84	660
Fundao	*1968*	*M*	13	12	14	16	21	24	30	30	24	24	14	11
Fundao	*1968*	*m*	1	5	6	7	10	14	16	16	13	11	7	5
Fundao	*1968*	*x*	-4	-2	0	0	3	10	10	12	7	8	3	-3
Fundao	*1966*	*h*	59	66	291	206	340	348	371	346	243	172	154	195
Fundao	*1966*	*e*	54	54	146	112	204	185	287	265	229	90	62	70

‡ r = rainfall in mm; M = monthly average of daily maximum temperature in Centigrade; m = same for daily minimum; x = extreme lowest temperature during the month; h = total numbers of hours of sunshine; e = total monthly evaporation potential in mm.

Forest and Heathland. — On the north facing slope south of the main stream and east of Sobralinho were formerly chestnut groves (*Castanea sativa* Mill.), managed for chestnuts and for wood for lintels and bridges. These trees were cut in the 1950's and 60's for sale to the hardwood furniture industry. A few regenerating stumps remain. The area was replanted in maritime pine (*Pinus pinaster* Aiton). Oaks (*Quercus* sp, perhaps *Q. suber* L. or *Q. ilex* L. among others) used to grow on the steep, south-facing hillsides. These supplied firewood, oxcarts, floorboards, toolhandles, etc., but are now replanted also in maritime pine. Above the steep upper slopes, where the ridge tops level, are heathlands. (The names of the nine principal species of heathland plants are given in Table 3 below.)

Crops. — Rye, corn, potatoes (*Solanum tuberosum* L.), beans (*Phaseolus vulgaris* L.), and collard (*Brassica oleracea* L.) are staple annuals. Perennial woody fruit-bearing plants include fig (*Ficus carica* L.), olive (*Olea europaea* L.), apple (*Pyrus malus* L.), quince (*Cydonia oblongata* Mill.), raspberry (*Rubus* sp), walnut (*Juglans regia* L.), chestnut (*Castanea sativa* Mill.), and marginally grape (*Vitis vinifera* L.). Rye is planted (now in terraces) at the beginning of the rainy season, grows vegetatively through the cool wet winter, flowers in the warmer spring, and the dry seed is harvested in late spring. The fact that rye is no longer cultivated in the heathlands may explain why the 1940 population estimated from terraces is more than that estimated below from baptisms.

The variety of collard, called *cove* in Portuguese, grows in the cool wet winter. It is planted in late summer as seed in a small, crowded, irrigated patch, and at the beginning of the rains, is transplanted at 0.5 m intervals. During the cool, wet winter, it grows to a height of two m and produces broad, thick leaves, which are eaten all winter long as a source of fresh vegetable, yielding vitamin C and fiber. Its inclusion in the diet contributes to the health and longevity of these robust people.

Corn is planted in the spring in irrigated plots. With adequate irrigation, it thrives in the hot summer. Ears are not harvested until late September before the rains start but after the grain had dried. *Cove* is often transplanted into the plot where corn grew in the spring and summer, and occupies it during the fall and winter. By contrast, rye cannot be grown to seed in plots where corn is to be grown because it does not mature in time for corn to be planted. Rye is sometimes planted in corn plots to help hold the soil in the torrential rains of winter, but is fed to goats before it flowers, so that corn can be planted.

Corn is planted two seeds per hill about 40 cm apart in all directions. When the stalks are about a 0.5 m high, the corn is thinned. From hills with two surviving stalks, one is removed and fed to goats. A few bean seeds are then planted around the base of the remaining stalk. During the summer, as the bean vines climb the corn stalks, the lower corn leaves are removed and fed to goats. Beans are harvested by pulling up the corn stalks after the ears have been removed, at which time the bean seeds are dry. Most organic matter that goats cannot or will not eat is buried in the soil. By contrast, corn stalks are pulled out by their roots and burned.

Sometimes beans are planted without corn, which, as the cultivators explain, gives the plot a rest. Non-climbing varieties are used for this. Pumpkin (*Cucurbita* *pepo* L.) is often planted along the upper wall in these plots. Potatoes are planted earlier in the spring than corn but, later in the spring, need irrigation to flourish. Their harvest is able to begin in May, providing an early staple, and continues through the early summer. Potatoes are harvested too late to allow corn to follow them, but beans can be planted. During the warm seasons, in irrigated kitchen gardens near the dwellings, an array of vegetables is grown, including lettuce (*Lactuca sativa* L.), onion (*Allium cepa* L.), carrot (*Daucus carota* L.), tomato (*Lycopersicon esculentum* Mill.), and garlic (*Allium sativum* L.).

Demographic history. — An inscription on a building in Pamilhosa da Serra states that King Dinis awarded the surrounding area as a fief to one of his nobles in 1308, but the earliest written record of habitation by a specific person that I found is a baptismal record from 1667. Records of parish rituals associated with birth, death, and marriage in the Pracais valley are nearly continuous since that date, and clearly indicate that the valley was well populated long before the mid 17th century. I have no direct evidence of the agricultural technology employed in the 16th and 17th centuries, but it is clear that the soil was naturally infertile, having weathered from the same ancient shales, and that the steep hillsides were then equally prone to soil erosion. Thus, it seems plausible that terraces were already in use to retain soil of sufficient depth and to control erosion.

I estimated the Ribeiros population in 1900 and in 1940 from baptisms to be about 131 and 260 people respectively. In 1987, 23 people lived in Ribeiros and cultivated only about 1/12 of the area of the terraces, the rest being left uncultivated. Residents confirm that in the 1940s every terrace was cultivated. Assuming a constant ratio of people to terraces, I estimate about 276 people in 1940, close to the estimate based on baptisms.

Residents tell me that the first road capable of carrying a motorized vehicle was built by hand in 1942, preliminary to the construction of the power dam near Cabril, and that most people there had never seen a motorized vehicle before that time. Thus it seems plausible that in 1940 the Ribeiros traditional, pre-fossil fuel agricultural technology was intact and capable of supporting 250+ inhabitants.

In 1987 Ribeiros still had at least 23 permanent residents, who told be they had been born there, or had come there to be married, and still remained. All were over 60 except for three young adults. Two were sons of a family that no longer farmed. They left the village daily with their father to labor for wages. The last was a farmer's daughter who worked with her parents. Four married couples and five single women still actively raised crops for much of their livelihood. The remaining five-six people lived mostly on pensions or savings but planted a few crops. There were no children nor single elderly men.

Addition of Organic Matter to Soil. — The principle means for maintaining soil fertility is to add organic matter to the soil. This organic matter consists mostly of brush, cut from the heathlands. Every active cultivator kept at least a few goats. Three or four days a week, a cultivator will take his or her goats, and often another's too, up to the heathlands. While the goats are grazing, the cultivator harvests brush. A heavy sickle is used to cut the bushes about 2 cm above the ground. An area of one or more m^2 is clear cut leaving nothing but stubble. Formerly the brush har-

FIGURE 3.— A bundle of brush about to be carried from the heathland where it was cut, down to a goat shelter in the village below. Photograph by the author.

vest might have been transported to the villages by ox cart, but now there are no more oxen, so it is piled into a bundle, tied with a single loop of rope, hoisted onto the head and carried down the hillside and back to the village (Figure 3). Often a piece of cloth protects the head and neck from thorns and prickles, with which this brush is replete. Typically, the brush bundle will be as large as can be reasonably carried; in the case of one strong farmer about 65 years old, a bundle he was carrying down the steep path back to the village weighed 42 kg.

Not all of the stone buildings are residences; some serve for storage on their main floor, and house goats at night in the basement. The brush is carried to these buildings and spread on the basement floor, to be enriched by goat excrement. I did not observe the inclusion of any other organic wastes with this brush. Enriched brush is removed about every two weeks and piled outdoors nearby (see Figure 4). Now called *estrume*, it will eventually be transported to the cultivated plots where it will be dug into the soil with large hoes, though formerly it might have been plowed into the soil with cow- or ox-drawn plows. Other organic wastes, including human, pig, and chicken excrement, were dug directly into the soil of nearby kitchen gardens.

Data to determine the rate at which farmers added estrume to cultivated plots following a corn harvest are given in Table 2. Eleven baskets of about 20 kg each (220 kg) of wet estrume made a pile of about 1.33 m^3. About one thirds of the wet weight of estrume is water. Thus dry weight of one cubic meter of estrume is estimated to be about 110 kg. This estimate was used to calculate dry weight.

TABLE 2. — Rate at which estrume is added to plots cultivated in corn.

Location/type	D	V	W	P	R
Sobralinho terrace; farmer not interviewed	2.6 x 1.4 x 0.7	2.5	275	220	12.5
Lower streamside traditional, corn yield estimate plot "d," Table 4.	3.5 x 1.0 x 1.6	5.6	615	440	14.0
Upper streamside traditional, followed with forage rye	2.8 x 1.0 x 2.0	5.6	615	470	13.1
Sobralinho terrace, same farmer as above, followed with fallow	1.8 x 1.1 x 1.4	2.8	336	505	6.7

D = dimensions of compost pile in meters; **V** = volume in cubic meters; **W** = dry weight in kg; **P** = plot size in square meters; **R** = rate in metric tons per hectare.

FIGURE 4.— A pile of brush that has been removed from the floor of a goat shelter, ready to be buried in the soil of cultivated terraces. Photograph by the author.

Nutrient replacement rate. — Corn yield in a cultivated plot was estimated to be 5,800 kg dry seed per hectare. Applying the rates of Barber and Olsen (1968), an estimated 116 kg N, 24 kg P, and 119 kg K are removed from the soil by the corn plants harvested from each hectare. Table 3 presents the concentration in g dry weight per kg of some agriculturally important elements present in estrume and in the various species of heathland bushes. These data can be used to estimate the rate at which estrume would need to be added to the soil each corn harvest to replace the nutrients removed by the corn in that harvest. Because 1.44% of estrume is nitrogen, 8.6 dry metric tons would be needed to replace the nitrogen removed from the soil in one corn harvest. Because 0.36% of estrume is phosphorous, about 6.8 metric tons of estrume are needed, and similarly about 9.0 metric tons for potassium. By comparing the values in Table 3 for vegetation sampled directly from

TABLE 3. —Dry gm / kg of elements in vegetation and estrume samples. Scientific names according to Franco (1971, 1984).

	N	P	K	Ca	Mg	S
Estrume	14.4	3.8	13.2	4.6	2.9	1.7
Calluna vulgaris (L.) Hull	5.8	1.0	1.7	2.4	1.0	1.0
Erica umbellata L.	9.0	0.6	1.2	1.6	0.9	0.7
Halimium ocymoides (Lam.) Willk. In Willk. & Lange	5.9	0.8	1.6	2.1	1.3	0.8
Lithodora diffusa (Lag.) I. M. Johnson	6.3	1.0	1.8	2.4	1.2	0.9
Erica cinerea L.	6.4	1.6	4.2	2.9	0.9	1.0
Chamaespartium tridentatum (L.) P. Gibbs	4.8	1.0	2.6	1.8	0.9	0.8
Ulex minor Roth	6.4	1.4	2.1	3.8	1.0	0.6
Genista triacanthos Brot.	12.4	1.0	3.4	1.3	0.9	0.9
Erica arborea L.	8.6	0.6	2.0	1.0	0.8	0.6

TABLE 4. —Analyses of soil samples representing plots of interest.

	F-W=A	O	N	P	K	pH	cxc	x
a. Uncultivated clay	27-11=16	0.9	1.0	2	70	4.8	9.5	2.4
b. Shallow soil from heathlands	31-11=20	7.9	3.1	39	174	4.7	14.5	3.8
c. Terrace irrigated Cultivated	34-12=22	7.5	3.6	366	378	4.9	20.0	6.4
Same plot 20 cm	32-12=20	5.2	2.7	188	126	4.7	17.7	4.3
Same plot 40 cm	31-10=21	5.2	1.7	34	96	4.5	13.6	3.3
d. Streamside irrigated Cultivated	36-12=24	6.2	4.3	89	169	5.7	23.4	12.2
e. Streamside irrigated abandoned 2 yr	35-17=18	8.8	4.5	206	142	4.7	21.7	7.0
f. Streamside irrigated abandoned 4 yr	33-15=18	8.8	4.8	53	126	4.4	12.7	4.2
g. Streamside irrigated abandoned 20+ yr	36-17=19	9.3	5.3	39	196	4.6	16.4	4.7
h. Terrace irrigated abandoned 9 yr	27-12=15	6.2	2.8	50	126	4.3	9.2	3.1
i. Terrace unirrigated abandoned 30? yr	33-14=19	7.3	3.8	14	215	5.0	22.3	6.9

F = field capacity; **W** = permanent wilting point; **A** = available water; **O** = organic matter; (F, W, A, O in %); **N** = total nitrogen (in g/kg); **P** = phosphorus; **K** = potassium; (P, K extractable in mg/kg). **pH** = titrated in water; **cxc** = cation exchange capacity; **x** = exchangeable Ca, Mg, K, and Na; (cxc, x in cmol(+)/kg). Sample at 5 cm depth unless otherwise noted.

the plants with values for estrume, the effect of the goats is easily seen. They approximately double the nitrogen, triple the phosphorous, and increase potassium several fold. Residents said that when they were young, the village was full of people, every terrace was cultivated, and there were hundreds of goats. There were about 25 goats in Ribeiros when I was there. Using the same 12:1 ratio of total to cultivated terraces cited above, indicates a goat population in 1940 of about 300, which would have been needed to maintain fertility in all the cultivated terraces.

Soil analyses. — Table 4 presents values for 10 measurements of each of nine typical samples from plots that represent the various situations of interest to this study, as described above. These data are available on request.

How much heathland is needed? — As noted above, soil fertility in cultivated plots is maintained in large part by adding to soil heathland brush enriched with goat dung. The rate at which brush grows limits the rate at which it can be harvested to replenish cultivated soil. Harvesting brush yielded 1.25 dry kg/m^2 in areas last harvested four years earlier, and 3.3 dry kg/ m^2 in areas that had been burned eight years earlier. This gives average annual productions of 312 and 410 dry gm/ m^2. Since burning the vegetation produces ashes that enhance plant growth, while removal of vegetation to make estrume does not, the higher of the two estimates of the regeneration rate of harvested brush is somewhat too high. Furthermore, these experimental harvests were taken from areas of heathland where brush grows well. As much as one third of the heathland is outcrop, boulders, or cart tracks, where little vegetation grows. Thus, assuming 12 metric tons of brush are required annually for each hectare cultivated, approximately six hectares of heathland are needed to grow the brush to replenish the soil in that cultivated hectare.

DISCUSSION

The climate and weather patterns, with very hot dry summers and cold, rainy, overcast winters, the steep crumbly terrain so difficult to even walk over, and the inherently infertile soil raise the question of why people should ever have settled the Pracais valley, and why they did not starve before they developed the agricultural technology that has nourished them for the past half millennium. Acquiring the data to answer this convincingly was beyond the scope of the present study, but other authors have suggested patterns that may apply here. Underdown (1985) points to a tendency for more marginal land to be owned and occupied by families who farm it themselves for subsistence, perhaps to avoid the exploitation following the concentration of wealth typical of economies built on fertile, easily farmed soils. Thirteenth and fourteenth century plagues killed about 40% of the population, mostly in concentrated urban areas. People may have sought unoccupied, and hence marginal, lands to escape this threat of death. Reduced populations made it difficult for the exploiting class to separate people from the land, so subsistence agriculture prospered, commercial agriculture waned, and urban centers experienced a shortage of grain (Oliveira Marques 1977).

The use of brush as a source of organic matter for soil enrichment in northern interior Portugal is probably quite old and widespread. It is explicitly discussed by Lacerda Lobo (1787) in his prize winning essay about the maintenance of soil fertility in the absence of animals. Bella (1805) writing about Portuguese agriculture states (p 154) that those who intend to grow more for themselves depend on brush to fertilize their cultivated land. Motta Prego (1897), in one of his many novels written near the turn of the 20th century to encourage young adults in northern Portugal to become or remain farmers, describes the cries of the ox-cart drivers as they return in the evening from the hill tops with their loads of cut brush.

Comparison in Table 4 of the soil in an organically enriched plot with the uncultivated clay of plot "a" clearly shows the contribution of increased organic matter. But the abundant organic matter in the cultivated soil of Ribeiros does more than provide nitrogen, phosphorous, and other nutrients. According to Magdoff (1992), organic matter facilitates the penetration and retention of water during irrigation, which is important for keeping crops supplied with water during the dry season. It facilitates the penetration of water during rains, which increases absorption and reduces surface erosion. It glues the soil together to help resist erosion during the heavy rains of winter. Organic matter increases the soil's capacity to hold and release ions, which is important for soil-root interactions, and it maintains the ecosystem of microbial and fungal life, which mediates the passage of nutrients to plants.

Plot "b" in Table 4, a heathland plot, is high in organic matter but, because it does not benefit so much from goat excrement, decomposes slowly and erodes rapidly. A comparison with other cultivated plots in Table 4 further shows how goats contribute. A few goats are milked, and occasionally one is eaten, but perhaps their most important contribution is to the maintenance of soil fertility. This has an importance beyond simply adding more nutrients. Goat excrement increases nitrogen and other nutrients and decomposes carbon more efficiently relative to the carbon in the brush. Griffin (1972) suggests that the species that make up the community of decomposers are largely determined by the ratio of carbon to nitrogen and other nutrients. Thus goats may also alter the species composition of the decomposing community in favor of those that thrive at higher nutrient levels.

One might ask why nitrogenous wastes of the other domesticated animals, such as chickens and pigs, not to mention human wastes, are not added to the brush with the goat excrement. As noted above, these types of excrement are buried instead in kitchen gardens. Perhaps it is to minimize the transmission of disease. Their wastes do not represent outside inputs. By contrast, goats, like the brush itself, gather nutrients from many km^2 and concentrate them in nearby cultivated soil. Sheep, cows, and sometimes pigs render this concentrating service in other agro-ecosystems. Here the terrain is steep and the rock is crumbly; the light, agile, sure-footed goat, unlike other domestic animals, ranges safely throughout the whole area. In addition there is very little grass but mostly forbs and shrubs, which goats eat more readily than these other animals.

Farmers often treat their goats affectionately, as if they were pets. No effort is made to herd or restrain the goats. They willingly follow farmers, who refer to their brush gathering activities as providing food and bedding for their goats, but the goats neither eat it (much) nor sleep on it. Farmers know that the brush is to maintain the fertility of their soil, but will still explain brush gathering in terms of goat care. Estabrook (1994) discusses this and several other explanatory anomalies in the tradition of these farmers. Perhaps 30% of the total time spent on economic activities by a farmer is invested in goats, harvesting and hauling brush, and making and hauling estrume. People say that in the past, brush was brought down in ox-carts. A few years ago someone was killed when he lost control of an ox-cart and now people say that they are too old to manage oxen safely. Oxen consume a great deal of food. There is virtually no pasture in this terrain, so ox food has to be grown. Thus oxen must be kept at work to amortize their operating costs. The need for ox food in the past results in an overestimate of population based on cultivated area. I saw no oxen resident in Ribeiros, but one farmer said he borrowed an ox from the nearby village of Vidual to plow. Several broad paths lead from residential areas up into the brush meadows and stop. These paths often crossed outcropped bedrock, where wheel ruts, worn by ox-carts into the soft shale, could be seen, evidence of the importance of oxen in the past.

Bearing in mind that corn yields may vary from plot to plot, that estrume and corn constituents may vary from our estimates, and that cove, beans, or winter rye may also be grown during the rest of the year (except when farmers fallow, which I suspect is not a traditional practice but evidence of the demise of traditional agriculture), it is apparent that farmers are approximately replacing with estrume the nutrients removed from the soil by the plants they harvest.

It is not surprising that the rate of soil replenishment by the addition of organic matter is sufficient to replace the nutrients removed and to maintain water holding capacity and tilth. After all, people have been raising crops in this soil for hundreds of years. The mechanisms suggested by the data are of interest. Azevedo and Ricardo (1973) suggest that the clay is weathered from precambrian shale, perhaps in its second or third soil cycle. From sample "a" in Table 4 it is clear that the native clay is low in plant nutrients, intrinsically acid, low in cation exchange capacity, and with few exchangeable cations. The addition of organic matter raises available water capacity somewhat, substantially increases nutrient levels, has little effect on pH, and substantially increases cation exchange capacity and availability, as shown by comparison with other samples in Table 4. It is possible that the cultivator of plot "c" added commercial phosphate or potassium fertilizer to the soil there because these values are conspicuously high, compared to plot "d," the other cultivated plot of Table 4. Plot "d" — in which I estimated corn yield and rate of addition of organic matter — was cultivated by a 67 year old man and his wife, who were my hosts. Trucks selling fertilizer do pass through the village. One frail lady in her 80s explained to me that she used fertilizer because she was too weak to carry brush any more, making it clear that people understand that brush does replenish soil nutrients, and that they proudly work on behalf of their own family even if they are its only remaining aged member. Plot "c" was in beans following potato, so rate of organic matter addition could not be measured because none was brought to that terrace during the five months I was there. However its 74 year old male cultivator did collect copious quantities of brush for his goats' bed, making it clear that people did understand that organic matter was not just to replenish nutrients.

Another natural question also beyond the scope of this study is why a culture, with its attendant technology, that was thriving with hundreds of practitioners in the villages of the Pracais valley in 1940 has dwindled to a few practitioners in 1987 and to virtually none in 1997. Caldas (1981), Serrao (1982) and Brettell (1986) state that in the 1930s traditional agricultural technology was still practiced in most villages in northern interior Portugal but emigration, especially of men, had begun. Roads and motor vehicles may have reached some villages by this time, facilitating government (exploiter class) tactics, such as taxation and conscription, that separate people from the land and force participation in the cash economy. Under the dictatorship of Salazar, suppression and exploitation of the lower classes was apparently so intense that it was clearly preferable to emigrate into menial laborer positions in other countries, lead frugal lives, and send money home to Portugal. In spite of harsh government laws prohibiting emigration, by the 1960s the exodus was rampant, contributing to the demise of depopulated villages, especially after a generation is born and raised in exile, where the invisible transmission of their culturally informed technology does not occur.

Since the 1970's, many emigrants have returned to their native villages to retire. They bring pensions and savings with which to create demand for food, brought by trucks into the villages and exchanged for cash. The residents of the village of Pracais are now nearly all retirees who live in original dwellings but no longer practice subsistence agriculture. By 1987 in the Piscansecos, many young inheritors had converted the dwellings of their deceased ancestors to vacation homes with running water, disregarding traditional mores for water sharing and human waste management. This led to overt hostilities from the older, permanent residents, decimating the cultural basis of their technology. Although aging, many of the permanent residents of Ribeiros still practiced aspects of their culturally informed subsistence agriculture and depended on it in large part for their livelihood. My glimpses of this way of life suggested that it depends on three generation households in which people of all ages had useful roles to play. The attraction of young people away from their culture and land seems to be an integral part of the process by which this culture dissolved. A few young Portuguese desire to return to the culture and land of their grandparents, but Portuguese society in the late twentieth century, under first the dictatorship and then the revolution, seems to have lost access to its the culturally informed traditional agricultural technology. Some rural parishes have avoided demographic demise by undergoing the transition to modern commercial agriculture. Pearson *et al.* (1987) and Bentley (1992) discuss the transition of agriculture in Northwest Portugal to modern technology.

Of the land cultivated in Ribeiros in 1940, less than 10% was under cultivation at the time of this study. However, the centuries of investment in the building of retaining walls, and in the creation of the organically rich soil behind them, does not rapidly deteriorate when terraces are abandoned. Rarely were walls in need of repair, and then mostly where they were actively driven or walked over/behind, or where water had been allowed to escape from ditches that had been built to carry it safely away. Most walls holding long abandoned terraces were in good shape. Especially where vegetation cover has grown thick, soil has remained in abandoned terraces. As shown in Table 4, this soil maintains its high level of organic matter and much of its available water capacity and nutrient levels. In fact, except for plot "e" where goats are occasionally corralled, the abandoned plots show little of the beneficial effects of fallowing, so important in other agricultural systems.

If traditional technology and willing labor were available, many abandoned terraces could be brought back into cultivation with minimal preparation. After ten years or more, woody plants begin to establish, often beginning with wild black raspberry (*Rubus*), which is ubiquitous. Broom (*Cytisus*) and sargaso (*Cistus*) and eventually walnut, chestnut, and oak follow. Owners often plant olive or apple trees on their terraces in partial abandonment, hoping to get some harvest with minimal care. In this region, some apple and olive trees are grown productively when cultivated appropriately, usually not in terraces but on less steep hillsides. Pine has been planted in abandoned terraces and managed for turpentine and firewood. Whether planted or natural, trees are difficult to remove from a terrace to return it to annual crops. In some parts of the Pracais valley the pine and oak forests nearly obscure the ancient terraces on which they are now growing.

Very damaging to the continuance of traditional agricultural methods here is the practice of replacing the heathlands on the upland ridges with eucalyptus. Eucalyptus trees grow rapidly, producing a crop of marketable poles in a few years, but draw large quantities of water from the ground, so that the irrigation springs below yield less water and dry earlier in the summer. In addition, chemicals produced by eucalyptus retard the growth of other plants. In 50 years they have depleted the soil and no longer regenerate well, leaving stumps that are hard to remove from terrain that has become truly unproductive. Some who advocate replacing heathlands with eucalyptus trees do not fully appreciate how important heathlands are to the fertility and water supply of the cultivated terraces below them.

Forest fires have burned frequently and destructively through out Iberia in the past two decades. Damaso (1992) suggests that fires are set during the dry season by people with selfish interests. Oak and pine forests take longer to regenerate after a fire, but heathlands begin to regenerate the next season, and may be somewhat fire adapted. In 1991, a forest fire swept through the upper Pracais valley, burning the heathlands and destroying the trees. When I returned to Ribeiros in 1993, after two years of no brush with which to restore soil fertility most of the residents had gone to live with relatives elsewhere. They are unlikely to practice cultivation again.

Subsistence agriculture with pre-fossil fuel technology has largely ceased as a way of life in Portugal. In the region studied, traditional technology and culture seem to have sustained an expanding population for hundreds of years, with minimal spatially or temporally external inputs. The invasion of extrinsic social and economic influences seem more likely to explain its discontinuance; traditional subsistence agriculture did not fail technically nor deplete its local resources.

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BOOK REVIEW

People, Plants, and Landscapes: Studies in Paleoethnobotany. Kristen J. Gremillion, editor. University of Alabama Press, Tuscaloosa. 1997. Pp. xviii; 271. $29.95 (paperback). ISBN: 0-8173-0827-x.

One of the more inexplicable aspects of archaeology this century is that, despite growing recognition of the importance to human societies of plant resources, surprisingly little emphasis has been placed on the recovery and interpretation of those remains by archaeologists. There have been notable exceptions, of course, as represented by the work of Braidwood, Yarnell, Flannery, Watson, and others, and by the 1970s, paleoethnobotanical studies were regularly being conducted by a small number of practitioners across North America to produce an unprecedented wealth of